CHARACTERISATION OF A NEW JOINING STRUCTURE FOR APPLICATION TO SHIELDING BOXES MADE OF CONDUCTIVE PLASTICS

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Abstract: When using shielding boxes made of conductive plastics, the main problem is how to contact both parts of the box in a conductive way. A new low-cost joining structure has been developed and characterised. Both the joining structure as the characterisation method and procedure are discussed in this paper.

1. INTRODUCTION

When designing shielding boxes, the choice of the material is only one of the parameters to be taken into account in order to achieve a good shielding value. As shown in figure 1, other parameters are defining the final Shielding Effectiveness (SE) of the enclosure: slots and holes, I/O cables and appropriate filtering and the joining structure.

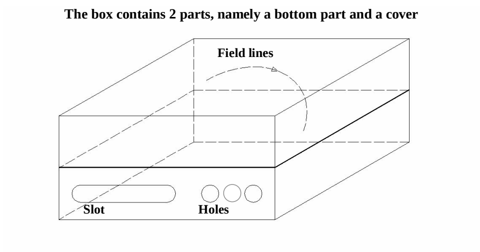

Figure 1. Joining structure for a shielding box

The decrease of SE due to a bad conductive joining structure is shown in figure 2. The measuring methodology and setup used for this purpose is discussed in detail in the next section 2.

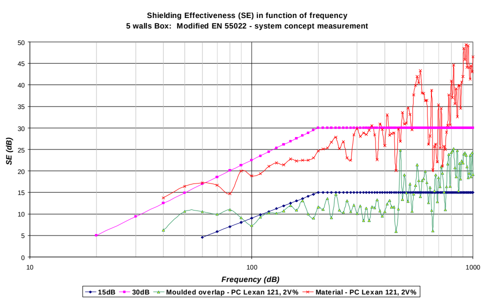

Figure 2. Decrease of SE due to bad conductive joint (lower graph) against material characteristics (upper graph)

The importance and the effect of good conductive joining structures is well known, and has been discussed in literature. Especially for stainless steel fibres injected plastics, the effect of metal inserts or screws has been reported in [1]. However, this method is relatively complex to apply, and other technologies has been developed to obtain a good conductivity at the surface of the plastic:

- removing the surface layer using a solvent, by mechanical scrapping, applying high pressured air, etc. ..
- extra injection of nano particles
- laser ablation of the surface layer

All techniques are intended to remove the bad conducting surface layer, which is rich of resin due to the injection moulding process, and to create a better conducting surface.

However, all mentioned techniques are still rather complicated or expensive. Therefore, a new technique has been developed, which combines low cost and simple to apply. This will be discussed in section 3 of this paper.

2. MEASURING METHODOLOGY

Shielding conductive plastics may be charactised following the standard ASTM D4935 [2], or similar configurations [3]. These measuring methods are intended for flat samples of material, but can not handle 3D joining structures. Therefore, a specific measuring set up has been developed and validated for homogenous flat samples.

As reference material, a polycarbonate PC Lexan 121 from SABIC-IP (GEplastics) has been chosen, and the SE was measured for far field conditions (using a TEM-t cell) and for near field magnetic conditions (using a H-t cell). More details about these measuring cells may be found in [3]. Measurements have been performed for a set of different volume percentage (0.25, 0.5, 0.75, 1, 2 and 3 V%) of the stainless steel fibres. They show clearly the dependency from the V% of the conductive filler, and the percolation effect around 0.5 V% is observed, when fibres start to create a homogenous conductive web in the material.

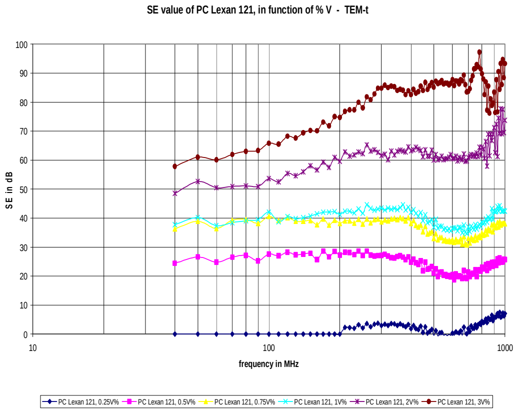

Figure 3. SE values for far field conditions (TEM-t cell)

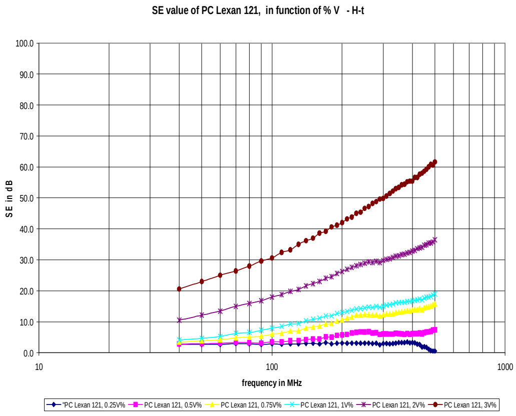

Figure 4. SE values for near field magnetic conditions (H-t cell)

In order to evaluate in an easy way joining structures, a metal box with an open side at one wall has been constructed. The samples to be tested are strongly clamped against this opening, so that a closed box is obtained. Large flanges are designed, so that mainly the samples should be measured and not the joining contact between sample and metal enclosure. The box is shown in figure 5.

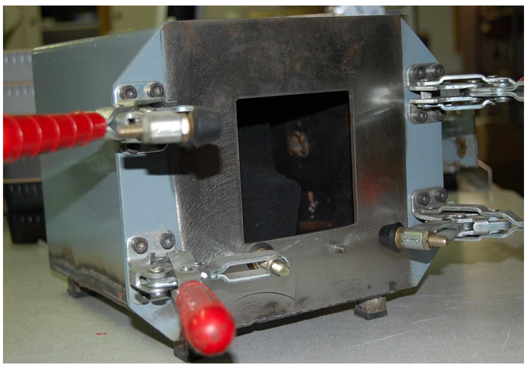

Figure 5. "5 wall" metal box with clamping mechanism to press the samples against the flanges

Inside the box, a small loop antenna is fixed, with an orientation, so that the induced current will cross the joining structure between the sample and the flanges of the open side of the box.

A generator is connected to the small loop, so that it is excited and simulates the radiation forthcoming from a PCB board. The system is installed in an anechoic room, and a logper antenna is placed at a measuring distance of 3m, as is normally done for EMC testing of apparatus, referring to the standards IEC EN 55022 or CISPR 22.
The incoming cable from the generator is put into a hollow pipe, which is connected to the walls of the anechoic room and the metal box. In this way, it can be assumed that there is no leaking radiation from this cable.

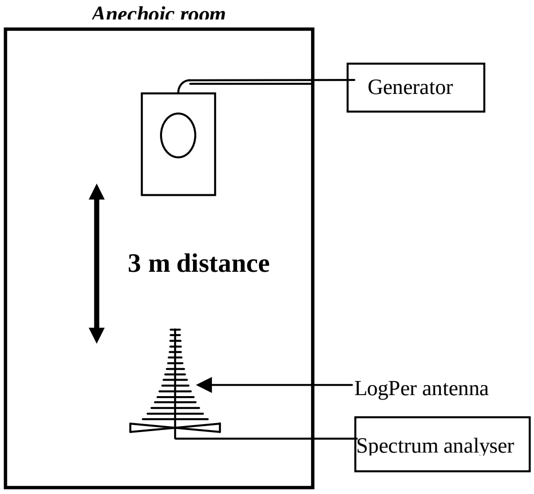

Figure 6. Schematic of the measuring setup using the "5 wall" metal box, and simulating the conditions of EMC testing following IEC standards

The same set of samples has been used for performing the SE measurements with this setup. The results are given in figure 7.

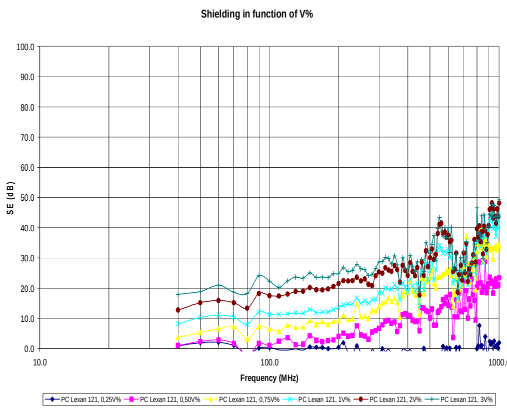

Figure 7. SE results using the „5 wall" box

First of all, a clear distinction between the different V% filler content is still observed, which shows already the facilities of this setup.
Furthermore, the set up is not simulating exact far field nor near field conditions, and also not the material characteristics only. It is already a combination of material, metal box and the clamping structure.

And finally, as the flanges were specially machined to be as flat as possible, the samples under test are not, so that only a rough contacting surface is created, and leakage may occur.
By putting some sheets of conductive fabric between the samples and the flanges (acting as a thin conductive gasket), an enhancement of the measuring system is obtained.

This setup will now be used for the evaluation and validation of a novel joining structure. For the purpose of this report, a filling content of 2 V% will be used, which provides a reasonable shielding effectiveness as basic material.

3. NOVEL JOINING STRUCTURE

As mentioned earlier, a novel joining structure has been developed, in order to combine a low cost manufacturing process and simple design.

The problem of joining two parts of a box is to maintain the conductivity over the joint, and to minimize the contact impedance between both parts, as sketched in figure 8.

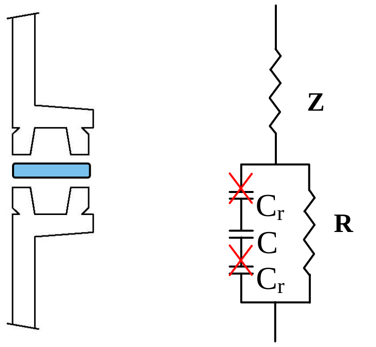

Figure 8. Conctact impedance of joining structures

By minimizing Z of the box material itself, and making the resistance of the joining structure R as small as possible, an optimized configuration will be obtained. In the case of conductive plastic enclosures made of injected stainless steel fibres, this is obtained by creating a conductive skin layer and inserting a conductive gasket in between both part, if necessary.
Due to the injection moulding technology, at the surface of the injected parts, a resin rich skin layer is obtained, with highly reduced conductivity at the surface, and the remaining fibres are even aligned with the surface, as can be seen in the next picture.

Figure 9. Picture of the resin rich skin layer

A technology has been developed, where a weak part can be removed by simply breaking it off, during the ejection of the injected part from the mould. In that way, a narrow conductive trace is created at the skin of the joining structure of the enclosure. The technology is patented EP 1886546 and US2008/0248230 [4] – [5].

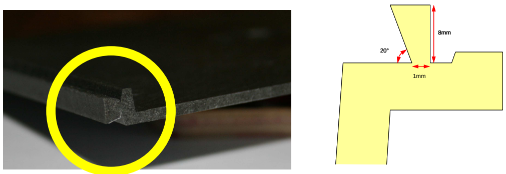

Figure 10. Breaking technology for injection moulding

A detailed view of this breaking section, can be seen in the next pictures.

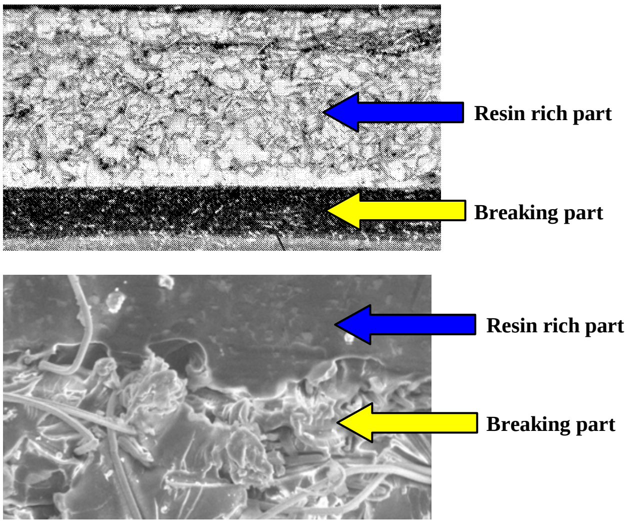

Figure 11. Detailed view of breaked skin layer

Two L shaped parts are now pressed together, so that they can be fixed on the open side of the “5 wall” box, as earlier described.

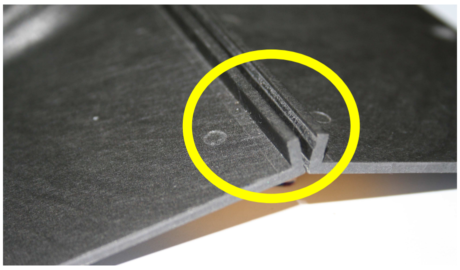

Figure 12. Combining two L shaped samples

Different applications can now be tested:

- just pressing both parts together, so that the two breaked zones are making a good conductive contact
- inserting an extra sheet of conductive fabric in between the two parts, so that a highly conductive contact layer between the two breaked zones is established

4. VALIDATION OF THE NEW STRUCTURE

As an example, the SE results for a LEXAN 121, 2V% sample are reported, in comparison with the homogenous material as reference.

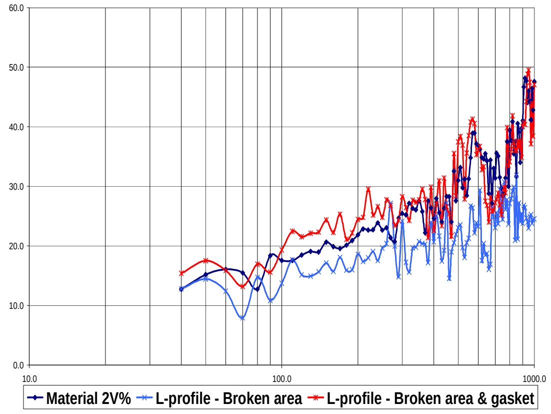

Figure 13. SE results for breaking technology

It is clear that no difference can be observed between the homogenous material and the breaking technology in combination with a thin sheet of conductive fabric or gasket.
Even the case where the two parts are just pressed together is performing well, certainly in comparison with the original moulded only situation. This is shown in the next figure 14, where the SE values of the homogenous material are compared with the breaking technology and the moulded only case.

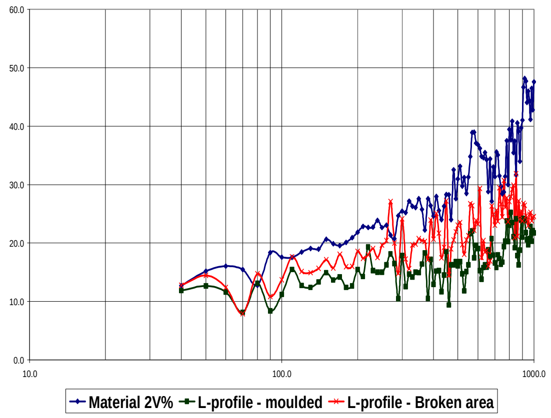

Figure 14. Comparison of SE for breaking technology and original moulded only case

For reference, a comparison is also performed between the breaking technology and applying metal screws, in order to hold both parts together.

As reported earlier [1], applying metal inserts to establish a good conductive joining structure in between both parts of an enclosures, tends to obtain the SE values that might be provided by the material itself.

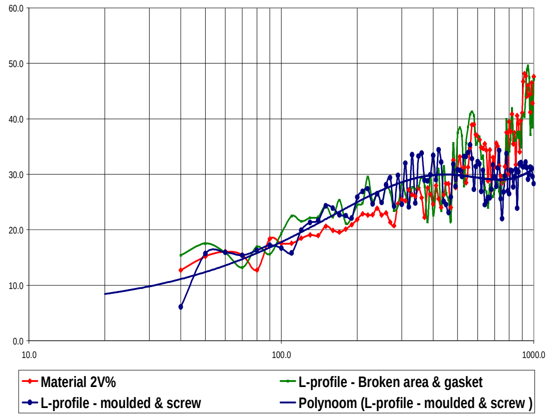

Figure 15. Comparison of SE values between screwed contact points and breaking technology

The breaking technology in combination with the application of a thin conductive sheet of fabric or gasket, performs as well as the homogenous material, or the optimal joint using metal inserts. It can be seen that the obtained SE of the latter method flattens at the higher frequencies, due to the leakage between two screwed contact points. By applying a gasket in case of the breaking technology, a continuous conductive layer is obtained, and no leakage is occurring.

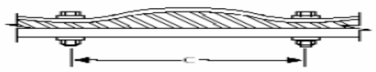

Figure 16. Openings between two screwed contact points

5. APPLICATION TO A FULL ENCLOSURE

Finally, a set of boxes has been injection moulded, in order to validate the new breaking technology structure under real conditions. The boxes are shown in the next pictures, as well as the measuring setup used. The orientation of the small loop antenna inside the test box generates an induced current in the shell of the enclosure, in that sense that it crosses the joining structures under test.

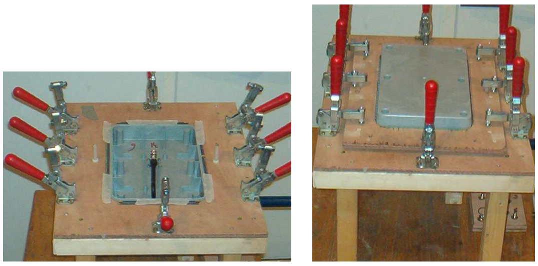

Figure 17. Pictures of the full box measuring set up

The measurements were performed in the same way as for the “5 wall” box, as described in section 2. Comparison has been made between a molded overlap, this breaking technology and laser ablation of the joining surface [6].

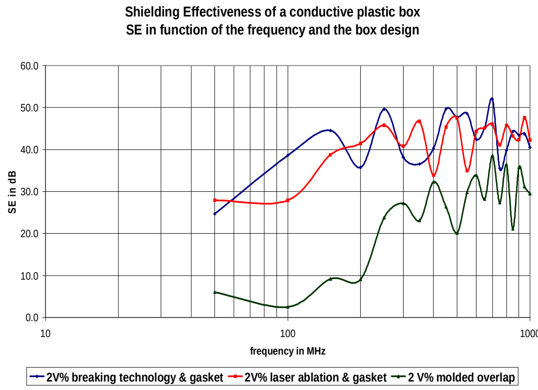

Figure 18. SE of full plastic box

It is clear that both breaking technology and laser ablation are providing the maximum SE possible for the material used in this case (ABS instead of PC Lexan 121). However, laser ablation needs an expensive investment in the laser equipment and a carefull control of the dosis of laser light applied, so that only the surface layer is scraped, and that the underlaying plastic will not melt again, enclosing and insulating the injected fibres.
Breaking technology can be directly applied during the ejection of the part out of the mold.
For the practical implementation, a typical design is shown in the next figure 19.

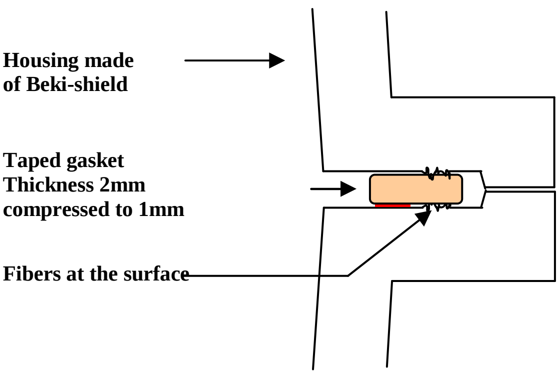

Figure 19. Practical implementation for box design

Both parts can be clamped together using a simple clipping snapfit, that can be clamped over the flanges, or designed in the walls of the enclosure.
The proposed design shows also the possibility to fix the gasket with tape or glue, out of the conductive zone, so that the overall conductivity is not affected.

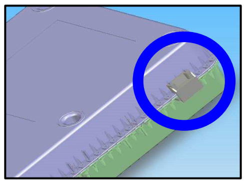

Figure 20. Simple snapfit mechanism to close the shielding box

More technical details concerning appropriate injection moulding parameters and design rules are given in the technical manual [7].

CONCLUSIONS

A novel technology to create a highly conductive surface layer has been discussed and validated. The breaking technology offers a simple manufacturing process combined with an easy, low cost concept to design shielding enclosures made of stainless steel injected fibres in plastics.
The novel joining structure provides a method of clamping two parts of an enclosure together, without loss of shielding effectiveness with respect to the material properties.
An appropriate evaluation and measuring method, which allows the validation of materials on the basis of small flat samples instead of full enclosures, has also been developed and discussed.

References

[1] J. Catrysse et al., “Study of the influence of conductive joints on the shielding efficiency of a conductive plastic housing”, Proc. 9th Int. Zurich Symposium on EMC, March 1991

[2] ASTM D4935-89 Standard, “Standard Test Method for measuring the electromagnetic shielding effectiveness of planar materials”, American Society for Testing of Materials, Philadelphia, USA

[3] J. Catrysse, “Measuring Results of the EM shielding effectiveness of different effects in conductive plastics”, Proc. IEEE Int. EMC Conference, Montreal, August 2001

[4] Patent EP1886546, “Polymer EMI housing comprising conductive fibre”, Bekaert nv

[5] Patent application US2008/0248230, “Polymer EMI housing comprising conductive fibre”, Bekaert nv

[6] Patent US6624383, “Using Laser Etching to improve Surface Contact Resistance of Conductive Fiber Filler Polymer composites”, Parker Hannifin Corp.

[7] R. Dewitte, “Application Technology for Beki-Shield® Feasibility in boxes”, Internal Report and Design Manual, Bekaert Fibre Technology, 2009